THE RELATION OF PLANT PHYSIOLOGY TO THE DEVELOPMENT OF AGRICULTURE.

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INTRODUCTION.

In a brief consideration of the relation borne by plant physiology to agricultural development it will be possible merely to call attention to some of the more important improvements in the art of agriculture that have resulted from the development of plant physiology, and to indicate some of the more important directions in which this science may affect the agriculture of the twentieth century. It will be necessary to call attention briefly to the origin of our cultivated plants, the discovery of the sexuality of plants, the discovery of the nature and sources of plant food, and the nature and causes of plant diseases. It will be desirable also to consider briefly the training in plant physiology required for the investigator, the teacher, and the farmer.

ORIGIN OF CULTIVATED PLANTS.

In its strictest sense, the word "agriculture" refers to the cultivation of the soil for the purpose of increasing the growth and yield of valuable plants. In its broadest sense, agriculture is the oldest and most fundamental of all the arts of civilization. The first steps in agriculture must certainly have been the simple stirring of the soil in search of edible roots, followed by the observation that plants grew better and yielded more abundantly in such stirred soil. The stimulating effect of excrement and decayed organic matter must also have been very early observed and practiced. In the early stages of agriculture the cultivation of special food plants in patches or fields on soils most conveniently located and easily cultivated and giving the best results was a simple and natural step even for the most primitive man. In accordance with the practice of all plant-eating animals, man selected for his use the individual plants which he liked the best and which produced valuable returns for him with the least labor on his part. Thus, there gradually came into existence selected and cultivated strains of plants better adapted than their wild progenitors to the uses of man. The changes or variations were slight at first, but we know from experience how greatly wild plants may be modified and improved by cultivation and selection.[a] Within a few years such treatment is often sufficient to make them almost unrecognizable. It is thus easy to realize how great the changes must be that are produced by centuries and centuries of such treatment under a great variety of conditions.

The process has thus been essentially a natural selection, man's like or dislike being the critical factor. Darwin was the first naturalist to fully comprehend this fact, and it was the study of variation under domestication and the history of domesticated plants and animals that enabled him to comprehend the great influence of continued selection in the modification and origin of species. Up to the time of Darwin, about the middle of the nineteenth century, the dogma of the constancy of species was almost universally believed. Species were held to be special creations, a theory which effectually answered all questions as to origin and stifled investigation. But regardless of any theoretical notions held by philosophers of that time, agriculturists realized the great importance of selection and crossing in the improvement and modification of animal species. Darwin quotes from Youatt, who, he says, was probably better acquainted with the works of agriculturists than almost any other individual. Youatt speaks of selection as "that which enables the agriculturist not only to modify the character of his flock, but to change it altogether. It is the magician's wand, by means of which he may summon into life whatever form and mold he pleases." He, of course, refers to the art of animal breeding, which is of very ancient origin and practice and differed from the practice of the early plant breeders in that hybridization and crossing, as well as careful selection, were followed by the animal breeders.

The sexuality of plants, however, was not known until comparatively recent times, and crossing and hybridization were not, therefore, consciously used in the early development of our agricultural plants. The first scientific proof of the sexuality of plants was furnished by Camerarius in 1691. It was not until twenty years later, however, that the first recognized plant hybrid was made.

PLANT BREEDING.

The knowledge gained in the early part of the eighteenth century was enlarged and somewhat improved in its scientific aspects, but was not put to much practical use until near the end of the eighteenth and the early part of the nineteenth century, when Thomas Andrew Knight, an energetic plant physiologist and horticulturist, gave the

[a] See Yearbook of the Department of Agriculture for 1896, pp. 89–106.

first great impulse to breeding as a method of improving plants. He recognized hybridization and crossing as the most potent means of inducing variations in definite directions, thus purposely producing changes which before were the result of chance development or which did not occur at all, and he was thus able to bring about desired modifications in a very short period of time. He recognized the slower method of inducing variation by cultivation and increased food supply, but realized that the changes that can be produced by selecting such induced variations are narrow and slow compared with what can be secured through hybridization and crossing, followed, of course, by careful selection to fix the desired types.

While there has been much advance in the scientific and practical knowledge of plant improvement in the last fifty years, we are still in the beginning of the work. In the earlier years of the nineteenth century most of the work that was done was in the nature of a refinement of the older methods of selection. The important bearing of the work of Knight was not fully appreciated, but recently there has been a rapidly growing recognition of the importance of hybridization and crossing. If it were possible to get at the facts, we should doubtless find that much of the progress in the past has been due to chance hybridization and crossing. The best that is in a variety can be brought out by selection, but when the plant does not possess desired characters they must be introduced by combining the good points of several varieties or species, either cultivated or wild.

A good start has been made in thus combining the European and native American grapes. The production of grapes for general purposes, which has been the aim of practically all the work on grape breeding thus far, has been accomplished and even carried too far, as is so clearly pointed out in Bailey's excellent work on the evolution of our native fruits. The great need now, as there suggested, is for varieties suited to special purposes, special soils and climatic conditions, and resistant to diseases and insect pests. These may be produced by combining the desirable qualities of our wild and cultivated varieties with the good qualities of the European types.

The combination of our native American plums with the older cultivated sorts has been in progress for little more than twenty years, but many new and valuable varieties have already been produced. Hardy varieties of apples are being produced by combining the qualities of our wild crab and of the hardy Russian sorts with the good fruit qualities of the cultivated varieties grown farther South.

Similar work is being done with the orange by combining the fine fruit qualities of the Florida sweet orange with the cold-resistant qualities of the hardy trifoliate or hedge orange, which is commonly grown in the North as a hedge plant. Hardy oranges of good quality have already thus been produced, as described in another paper in this Yearbook,[a] and their further improvement is assured.

Very valuable varieties of the pomelo have been produced by crossing this fruit with the tangerine. These are nearly seedless and have a loose rind like the tangerine, but retain the pulp characters of the pomelo. This new fruit is called the tangelo. The small, rather dry tangerine, by crossing it with the orange, has been made larger and more juicy without losing its other qualities.

Scarcely an important fruit, flower, or vegetable can be mentioned that has not in the past fifty years been greatly improved for certain purposes through the production of special varieties by hybridization.[b] More has been accomplished with fruits and with flower and vegetable crops than with any other classes of plants, but important advances have also been made with the cereals and forage crops by increasing yield and hardiness; and the work of the Department of Agriculture indicates that we shall be able to obtain by hybridization and selection drought resistance, alkali resistance, and resistance to rust and other diseases.

In nearly all our important crops greater improvements have been made within the last fifty years as the result of our knowledge of the causes of variation and the principles of selection and hybridization than have taken place before in historic times. This progress is the direct outgrowth of the discovery of the sexuality of plants and the laws of variation and heredity as applied to them. The physiologist is seeking to work out still more accurately the laws of variation, correlation, and heredity. When these are better understood, breeding will become a still greater power for the betterment of agriculture.

THE FOOD OF PLANTS.

Next to the development of physiological knowledge which furnishes the basis of plant breeding, the growth of knowledge relating to plant nutrition has had the most important bearing on the art of agriculture. The germ of our modern theory first became evident about the beginning of the eighteenth century. Previous to that time it was believed that plants obtained all their food from the soil, although the elements and compounds constituting even soil foods were not known.

The first step in advance was the demonstration of the fact that the leaves take part in the elaboration of food and that the larger part of the substance of plants is derived from the atmosphere. The lack

[a] New Citrus Creations of the Department of Agriculture, p. 221, of this volume.

[b] See Progress in Plant Breeding, Yearbook of the Department of Agriculture for 1899, p. 465, and Yearbook of the Department of Agriculture for 1901, p. 217; also, Hybrids and their Utilization in Plant Breeding, Yearbook of the Department of Agriculture for 1897, p. 383.

of chemical and physiological knowledge at that period, however, made it impossible to proceed far in explaining these observations. It was not until nearly the end of the eighteenth century that definite proof was furnished that plants absorb and fix the carbon dioxid of the air and give off oxygen in the process, at the same time assimilating the elements of water and increasing in weight in a corresponding degree. This process was found to take place only in the light and only in the green parts of plants, and normally and copiously only when small quantities of certain mineral matters were absorbed by the plant through the roots. It was also observed, about this time, that all parts of a living plant absorb oxygen and give off carbon dioxid, just as animals do in respiration. The conclusion was reached, though founded on imperfect experiments, that plants can not make direct use of the nitrogen of the atmosphere. The great importance to agriculture of these observations was soon lost sight of, however, in a mass of unimportant matters and misinterpretations, and it was not until the appearance of Liebig's work in 1840, and especially until the investigations of Boussingault, between 1840 and 1850, were made, that the error was cleared away and the important facts clearly set forth.

It has thus been scarcely more than fifty years that we have had information on the subject of plant nutrition that could profitably be applied to agriculture. During this period very rapid progress has been made in working out the more complex chemical and physiological problems involved in the absorption, modification, and assimilation of the several food elements under various conditions and from various compounds or sources.

The essentials for the growth of most of our cultivated plants are that they shall have favorable light, air, temperature, and moisture conditions for the growth of the leaves, stems, and fruits, and a favorable quantity of air and moisture in the soil, with such soluble compounds of nitrogen, phosphorus, potassium, calcium, magnesium, and iron as are best adapted to the particular crop.[a] The demonstration of these requirements has placed in the hands of the farmer the means of maintaining and increasing the fertility of the soil, and has enabled him in many cases to make soils productive that before were barren. The knowledge that plants need light and air and that the larger portion of their food comes from the air has brought about a modification of cultural conditions by giving plants more room in which to grow, with a consequently greatly increased yield. Based on a scientific knowledge of nutrition, the art of feeding plants has developed within the last fifty years in a most remarkable degree. The well-informed

[a] See Relation of Nutrition to the Health of Plants, Yearbook of the Department of Agriculture for 1901, and Fertilizers for Special Crops, Yearbook of the Department of Agriculture for 1902. Reference to other literature on this subject is given in the articles cited.

farmer now knows that the varying combinations of essential conditions and elements that occur naturally in different soils and climates are an index to the adaptability of these climates and soils for special crops. He knows also that these conditions can be modified favorably or unfavorably by cultivation and fertilization. He understands the importance of a physical and chemical examination of soils as indicating the presence or absence and the relative proportions of the essential elements of plant food.

The final test, however, is the physiological one of determining by actual trial whether certain crops are adapted to particular conditions and how the conditions may be made more favorable. The physiological examination should also determine what beneficial or injurious micro-organisms are present in the soil and the changes which these produce. There are some bacteria and fungi that cause the decay of the organic remains of animals and plants, leaving the nitrogen and other elements of plant food in the form of compounds available to crops. On the other hand, there may be present organisms which produce substances in the soil directly or indirectly unfavorable to crops. The life history and habits of all these forms must be carefully determined and the useful kinds put to work and the injurious ones eliminated.

Very little has yet been accomplished in this particular field except in connection with the problem of nitrogen fixation. Many investigators have worked upon the latter problem, and step by step the important facts have been discovered. The Department of Agriculture has had a hand in the later developments of this work. The physiologists of the Department have succeeded in working out the complete life history and habits of the root tubercle bacteria which, living in the roots of legumes, secure nitrogen from the atmosphere, thus enabling these crops to grow luxuriantly in soils devoid of this scarcest and most expensive of all food elements. Soils poor in nitrogen may, by the use of these bacteria and proper legumes, be enriched from the inexhaustible supply of nitrogen in the atmosphere. The nitrogen-fixing power of these bacteria has been increased more than fivefold by cultivation and selection on nitrogen-free media in the laboratory.

A cheap and thoroughly effective way of distributing and applying these organisms in general agricultural practice has been devised and put into use on a large scale. At a cost of a few cents a bushel, the seeds of clover, alfalfa, peas, beans, or any other legumes may be inoculated with these bacteria, thus making it possible to secure good crops on soils devoid of nitrogen, and at the same time leave a large quantity of this element fixed in the soil in a form available to wheat, corn, potatoes, or any other crop that may follow the legumes. The bacteria are helped to live and multiply by their host plant, the host in turn is supplied with nitrogenous food by these bacteria, and the host upon dying leaves its decaying roots, leaves, etc., to supply stored-up nitrogen to succeeding crops, or to neighboring plants which may outlive the legume and feed upon its disorganized parts. The value of legumes as restorers of fertility, apart from their value as food, has thus been greatly increased. These crops without the nodule-forming bacteria exhaust the nitrogen of the soil, like any other crop.[a]

This investigation, however, does not stop with the nodule-forming organisms. There are other bacteria known which have the power of fixing nitrogen from the atmosphere independently of any particular crop. It may be possible when the life history and habits of these species are fully ascertained to improve, cultivate, and distribute them as we do the tubercle forms. If this can be accomplished they will supplement the work of the tubercle bacteria and will add greatly to the world's supply of stored nitrogen, which is one of its greatest sources of wealth.

NATURE AND CAUSES OF PLANT DISEASES.

A third phase of plant physiological investigation which has resulted in immense benefit to agriculture has been the study of the causes, prevention, and cure of plant diseases. In the past, as now, very great loss in crop production has resulted from attacks by insect and fungus pests. It has been scarcely a century since the scientific investigation of plant diseases began and hardly more than half a century since enough has been known of plant physiology and of the life history, structure, and physiology of bacteria and fungi and their causal relation to diseases to be of any practical value to agriculture.

The rusts of cereals in damp seasons often destroy these crops or greatly reduce the yield and quality of the grain over immense areas, thus causing serious loss and suffering, and often famine. Many species of rusts have been discovered, some more destructive than others. The parasites causing the disease have been in some cases carefully studied, but much of their life history and habits remains yet to be learned. One of the most important facts discovered is that some of the most destructive forms, like the black rust of wheat (*Puccinia graminis*), have several distinct stages, formerly believed to be entirely separate fungi and to have no connection with each other. When De Bary found, however, that the cluster-cup rust of the barberry was a stage of the wheat rust and that the wheat was infected from the spores of the barberry rust a common observation of farmers was explained, namely, that wheat rust is most severe near barberry hedges. Laws were passed requiring the destruction of barberry hedges, and this particiliar form of wheat rust was then

[a] See Bacteria and the Nitrogen Problem, Yearbook of the Department of Agriculture for 1902; also, Bureau of Plant Industry Bulletin No. 71, and Farmers' Bulletin No. 214.

greatly reduced. The investigation also demonstrated that the black-rust stage on wheat could not infect the plant directly, but could infect the barberry, producing the cluster-cup rust of that plant. The spores of the barberry rust were found not to infect the barberry but the wheat plant, producing first the form known as the red rust on the leaves and developing later on the same plant into the black rust.

The red-rust stage of the wheat rust can not infect the barberry, but spreads the disease rapidly over wheat fields, producing a new generation about every two weeks. The great epidemics of wheat rust are due to this red-rust form of the fungus. If the season is moist and the spores from each generation are able at once to germinate, the multiplication is so rapid and continuous that before the grain is ripe the host plants are so overwhelmed by the quantity of the rust that their vitality is sapped and their supply of plant food to the developing seeds is so reduced in quantity that only a few and imperfectly developed seeds are produced. In some localities where this form can not live over winter it is simply necessary to get rid of the barberries, as above suggested, and the disease is eliminated; but in many places, especially in the great wheat regions of our own country, the red-rust stage of the fungus lives over winter on winter wheats, volunteer wheat, and perennial grasses, and possibly on other plants, and directly infects the wheat crop of the next season, as demonstrated by the investigations of this Department. Infected regions thus have more or less rust every year, but the prevalence of the disease depends more upon the conditions favoring or preventing the germination of the spores than upon the number of spores living over winter and present in the spring.

Fungicidal treatment for rusts has so far proved valueless, but much more investigation is needed along this line. The most helpful developments will doubtless be in the production of rust-resistant varieties through selection and hybridizing followed by further selection, thus, for example, breeding into the tenderer wheats the rust-resistant qualities of the durum and emmer varieties.

The smuts of wheat, oats, rye, barley, etc., form another class of diseases which have in past ages caused and still continue to cause immense loss. Pathologists have been more successful in overcoming this class of diseases. Where formerly from 20 to 40 per cent of the cereal crops were annually destroyed, now, by a simple and cheap treatment of the seed before planting, using formaldehyde, hot water, or copper sulphate, the loss may be reduced to less than 1 per cent.

The discovery by Millardet about twenty years ago of the remarkable fungicidal value of Bordeaux mixture was the starting point of the scientific and practical development of the use of fungicides, and has resulted in a very wide use of the compounds of copper for the purpose of preventing plant diseases. Several destructive diseases of potatoes, such as early blight and late blight, or potato rot, which often cause great loss to the growers of this crop, are now easily prevented by spraying the plants with Bordeaux mixture; and by adding a little Paris green to the mixture protection is afforded by the same treatment against the ravages of the potato beetle. The black rot and brown rot of the grape, which at one time practically destroyed the grape industry of the Central and Eastern States, have been carefully investigated and an effective remedy found in Bordeaux mixture. In fact, this mixture, which is a combination of copper sulphate and lime, has been found an effective protection against the larger number of parasites which attack plants through the leaves, stems, or fruit.

In the case of root diseases caused by parasites in the soil or other unfavorable soil conditions, the development of resistant strains or varieties is often the only method practicable. Much has been accomplished in this direction. For example, varieties of grapes have been bred resistant to the California vine disease, which has annually destroyed the industry in several sections of southern California. The phylloxera-resistant quality of our native grapes has been made use of in breeding resistance into the tenderer European varieties, and our native varieties have also been used directly as stocks on which to graft the tender European sorts. This procedure has saved the grape industry of Europe, and is being used to a large extent now in California to guard against phylloxera.

Strains of cotton resistant to wilt, a very destructive disease caused by a fungus living in the soil, have been developed by selection. Cowpeas resistant to root-knot and wilt have been produced, and a valuable new variety of watermelon, which will grow successfully in wilt-infected soils where other melons fail, has been developed. This was accomplished by combining the wilt-resistant qualities of the citron with the fruit quality of the melon by hybridization and selection. Flax varieties resistant to flax wilt have been produced. Considerable progress has also been made in securing by breeding and selection strains of important crops resistant to alkali.

While much has been accomplished in this phase of physiological investigation to enable the farmer and the fruit grower to guard against loss, to save great industries from destruction, and to establish new industries, there is still a much greater work to be accomplished. The life history of organisms causing disease has been thoroughly worked out only in a very few cases. The causes of susceptibility or resistance to disease in the host plant and the whole question of immunity have hardly been touched upon for most diseases. Diseases caused by unfavorable atmospheric and soil conditions and the relation of nutrition to the health of plants constitute a very imperfectly explored field.[a] Fungicidal and bactericidal treatment of diseases may yet be greatly improved. One possible direction of improvement in this connection is the finding of substances toxic to the pathogenic organism, but harmless to the host plant even when absorbed by the plant in quantity large enough to inhibit the growth or prevent the action of the invading organism. This has been accomplished in animal pathology in a number of instances. Recently the Department physiologists have found that water solutions of metallic copper or of copper sulphate, so dilute as to be absolutely harmless to man and the higher animals, are very destructive to the bacteria causing typhoid fever and Asiatic cholera, and to noxious algæ contaminating water supplies.[b] Copper sulphate has been used very successfully in destroying these contaminations of water and in connection with the arsenite of copper in treating typhoid fever. There is good reason to believe also that metallic copper in so-called colloidal solution will be found effective in treating certain other diseases caused by bacterial infection, and possibly also for cancer, as the writer suggested several years ago.

Briefly recapitulating, we see that our power to modify plants according to our needs has been very greatly increased and perfected by the development of plant physiology; that the working out of the nutritive requirements of plants has enabled us to maintain and increase the fertility of soils, to increase the yield and quality of crops, to prevent waste of valuable food elements, and to set to work and to improve nature's machinery for the accumulation of nitrogen from the atmosphere in combinations available to crops. It has also enabled us to discover the causes and find remedies for many of the most destructive diseases of crops. The result of all this in the last ten or fifteen years has been to enable the progressive farmer to protect and control his crops to a degree never before believed possible, and scientific farming is now fast becoming one of the safest forms of investment of capital and labor.

PLANT PHYSIOLOGY FROM THE EDUCATIONAL STANDPOINT.

It is evident from what has already been said that the science of plant physiology began with the farmer. The farmer made the first observations on the effects of cultivation and manuring. His success in the improvement of plants by selection and in the development of fine breeds of stock by crossing and selection was the key to the solution of the problem of the origin of species. The power to observe carefully and to draw correct conclusions has not been limited to

[a] See article on this subject in the Yearbook of the Department of Agriculture for 1901, p. 155.

[b] See The Contamination of Public Water Supplies by Algæ, Yearbook of the Department of Agriculture for 1902, and Bureau of Plant Industry Bulletin No. 64.

scholars and scientists. In nearly every industrial field the first great steps were taken by practical men, often with no special training other than that obtained by hard work, experience, and earnest thought in their chosen vocation. The explanation of this is that the practical workers were doing in the field and workshops the real experimenting and observing with a definite aim in view, and this is the foundation of the so-called modern laboratory method.

The remarkable developments in every branch of science and industry that have taken place in the past century have also been due in large part to the introduction of more accurate methods of study, observation, and interpretation, and the attempt by such methods, instead of those of scholastic philosophy, to get at the truth of things. For the development of these methods as applied to scientific investigation we are indebted very largely to chemistry and physics. It is not practicable nor profitable for the farmer or the mechanic to go deeply into experimental work. Their business is to produce, by the best-known methods or processes, with a net profit to themselves. In the field where plant physiological knowledge or investigation can aid the farmer it is the business of the physiologist first to consider the problems from the industrial standpoint and then to solve them according to the most accurate and expeditious methods. It is the aim of plant physiology to determine the nature and causes of all vital phenomena in plants, to determine their relation and importance to the life of the organism, and to discover the methods of controlling these activities. Our ability to control them is the proof that we understand their cause and nature. It is the application of this method of proof that has made applied science so much more productive of great discoveries and generalizations than so-called pure science. But in spite of the great advance that has been made in the art of agriculture during the last century as the result of the discoveries in plant physiology, chemistry, and physics, we have only begun to realize what the future has in store for us. The relation of plant physiology to the principles and future development of agriculture must finally be considered from the educational standpoint. What must be the training of the investigator in applied plant physiology, and what must be the training of the teacher, the farmer, and the horticulturist?

THE INVESTIGATOR AND THE TEACHER.

The training of the investigator in plant physiology, as in all other sciences, should logically begin in the primary schools. He should be taught how to observe and study the particular objects and phenomena of nature with which he comes in contact. It is the old method again of studying things themselves instead of studying books—applied, as it should be, in the very beginning as well as in the later stages of education. This fundamental training in the general principles of natural history can be accomplished, along with drawing, manual training, reading, writing, mathematics, history, geography, etc., by a process of natural development and growth instead of the cramming and forcing process so common even now in our schools. It is true that the lack of competent teachers makes it difficult to apply this method, but when we realize the need we will strive to meet it. In the end, the plant physiologist, besides a good general training in other subjects, must have an accurate and thorough knowledge of the general principles and methods of investigation in physics, chemistry, geology, meteorology, and general biology. The vital activities of plants are in accord with chemical and physical as well as biological laws, and can not be understood apart from environment.

Too much stress can not be laid upon the thoroughness and accuracy of this general training. In the haste to specialize, now so rampant, general training is too often neglected, this part of the education being discontinued too early; both general and technical education should proceed together. General biology must, of course, include both the animal and vegetable groups of living organisms. There must be a general survey of evolutionary development, a study of types from the simplest to the most complex, a study of comparative general morphology, anatomy, and physiology in the broadest sense, and finally a special knowledge from these standpoints of the vegetable kingdom in particular. This survey must lay special stress upon domesticated plants and animals as compared with wild species. It is such comparative study, as Darwin first forcibly demonstrated, that reveals Nature's secrets.

To gain this knowledge of cultivated plants it will be necessary for the plant physiologist to take a practical course also in agronomy and horticulture. The field, the orchard, and the garden are the best laboratories for this purpose. Throughout this training exact and accurate methods of physiological investigation must be acquired and the mind must be trained to sift evidence and draw accurate conclusions, to develop hypotheses and test them. Initiative must be encouraged and developed, and the economic relations of all questions must be appreciated.

Besides the training already described, the investigator in physiology must have a good reading knowledge of the more important modern languages, especially German and French. He must keep in touch with what other workers are doing in his own and related lines.

This very brief and imperfect sketch is presented not as an ideal, but as an absolute necessity for anyone who wishes to go into the real business of physiological investigation as it relates to agriculture. Experience has proved that men with such training can solve the difficult problems and can see and understand phenomena of the greatest importance that others have overlooked or have misinterpreted, and can greatly aid in plant production.

The teacher must have this same training and knowledge, and besides have the ability to encourage and help others to obtain it.

THE FARMER AND THE HORTICULTURIST.

The fine art of modern agriculture is as much beyond the uneducated and untrained man as the art of sculpture is beyond the ordinary quarryman. The poor of the cities can not be sent to the country and there made into farmers as easily as some superficial observers may think. The young man who would be a farmer or horticulturist must either be trained by some experienced member of the profession who has kept abreast of the times and has made a success of farming or horticulture, or he must go to an agricultural school, where agricultural training is made a business. A combination of both is still better. If a correct educational system has been followed in the common schools under competent teachers, the young agriculturist will have when he comes to the agricultural college a practical knowledge of farm operations and a good general elementary education, including a training in the elements of natural history, before described as desirable for the young physiologist.

It may be possible to obtain this training from the primary graded schools of our towns and cities. It is, however, much more likely to be secured through the newer system of consolidated rural schools now being adopted in our most progressive agricultural States. This rural-school system starts with a primary school and leads up to the agricultural high school and college of agriculture, and has as its aim, from bottom to top, the training of agriculturists. The system meets a recognized economic and educational need and is sure to take a place coordinate with the older systems.[a]

As a result of his study in the college, the young agriculturist must understand and be able to make use of the general principles of physics, chemistry, and geology, with special reference to soils, meteorology, and general biology. He must learn the reasons for the technical agricultural processes and be able intelligently to modify and vary these processes to meet varying conditions; he must be able to understand and make use of improved methods in agricultural technology; in short, he has to learn how to produce by the best and most economical methods.

The botanical training should consist of a general survey of the vegetable kingdom, with special reference to the origin, relationship, and physiology of cultivated plants and those of economic importance.

[a] See article by Hays, Our Farmer Youth and the Public Schools, in American Monthly Review of Reviews, October, 1903.

The economic relations of bacteria and fungi must be studied with special reference to controlling and protecting the valuable species and guarding against the injurious species. The farmer should be able to recognize the more important and destructive plant diseases and know how to guard against them. He must understand the principles of reproduction and propagation and methods of plant improvement by seed selection, cultivation, and hybridization. He must know how to maintain and increase the fertility of soils and must recognize the adaptability of soils to special crops. This involves a knowledge of food requirements of special crops and the most economical means of furnishing the required food. In a host of other ways also, a knowledge of the physiology of plants will enter into the technical processes of farming or fruit growing. The paramount idea should be not to make botanists, chemists, or zoologists, but to furnish the foundation training for the development of experts in farming, or fruit growing, or animal husbandry. There must be the closest sympathy and touch between the investigator, the teacher, and the practical worker. They are a trinity with a unity of purpose—the development of a perfect art of agriculture.